



National Aeronautics and Space Administration



NASA's Communications and Navigation Architecture Plans to Support the Return to the Moon and a Sustainable Lunar Presence

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Artemis: Landing Humans On the Moon



Lunar Reconnaissance
Orbiter: Continued
surface and landing
site investigation



Artemis I: First
human spacecraft
to the Moon in the
21st century



Artemis II: First humans
to orbit the Moon and
rendezvous in deep space
in the 21st century



Gateway begins science operations
with launch of Power and Propulsion
Element and Habitation and
Logistics Outpost



Artemis III-V: Deep space crew missions;
cislunar buildup and initial crew
demonstration landing with Human
Landing System



Humans on the Moon - 21st Century
First crew expedition to the lunar surface



Early South Pole Robotic Landings
Science and technology payloads delivered by
Commercial Lunar Payload Services providers



Volatiles Investigating Polar Exploration Rover
First mobility-enhanced lunar volatiles survey

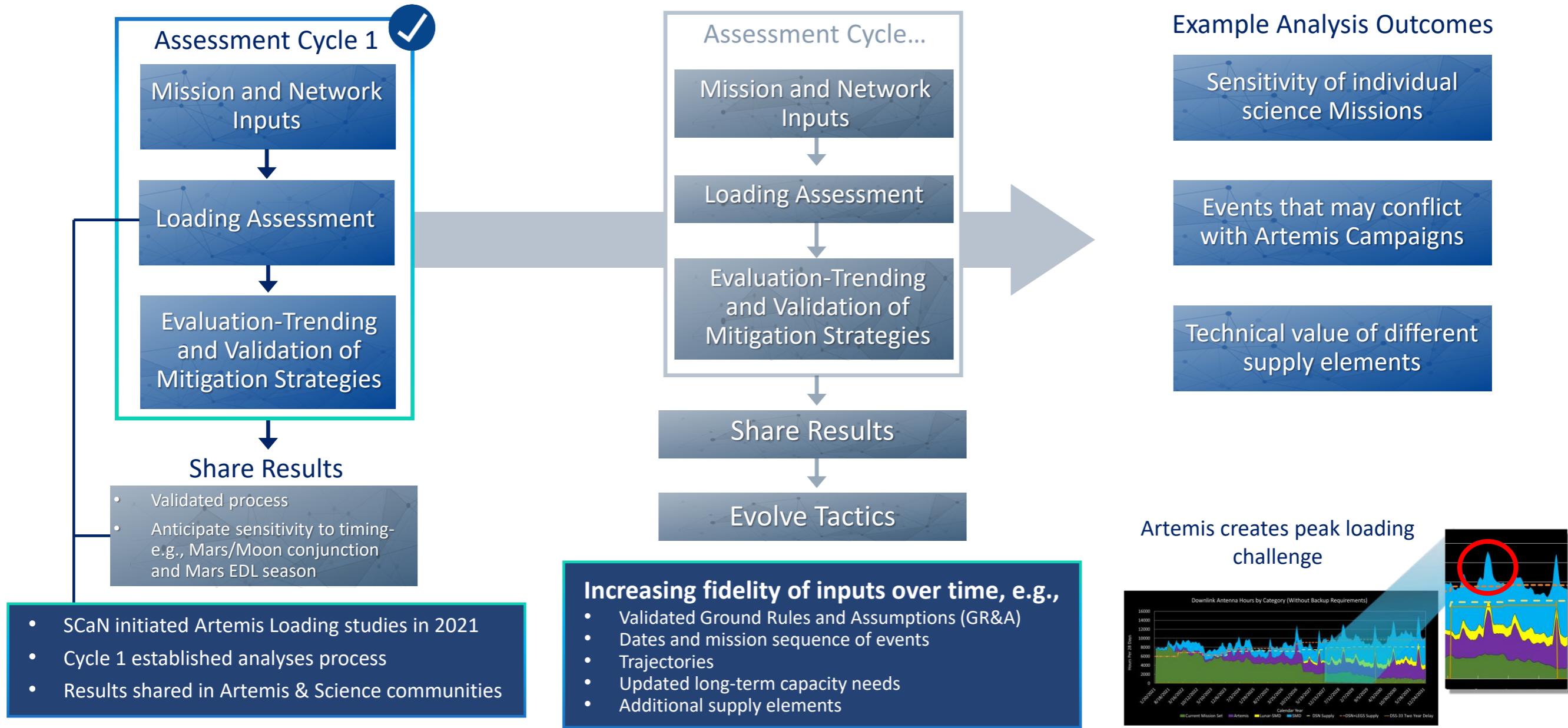


Uncrewed HLS
Demonstration



LUNAR SOUTH POLE TARGET SITE

Continual Assessment of Supply and Demand



Four Point Plan



Deep Space Network (DSN) Lunar Exploration Upgrades (DLEU)

- Upgrades to Six Deep Space Network (DSN) antennas (Two at each of the three complexes)
- Simultaneous operations – S+Ka-band or X+Ka-band, simultaneous Ka-band
- Increased data rates – greater than 100Mbps downlink in Ka-band



Lunar Exploration Ground Segment (LEGS) (18-Meter Class Antenna Subnet)

- A dedicated new set of antennas, designed to support lunar missions, to help alleviate the user load on the DSN
- Minimum of three sites around the Earth for continuous coverage
- NASA pursuing build of LEGS sites #1-3
- Commercial services to add additional capacity – add assets as demand grows and to meet redundancy / resiliency needs



Lunar Communications and Navigation Relay Services

- Removes DTE line-of-sight comm constraint & reduces user burden
- Initial relay deployment targeted at South Pole and Far-Side
- Networking and PNT services
- Commercial service procurement approach for the relay



International Partnerships and Contributions

- SCaN seeking contributions for both Earth based and Lunar C&N assets
- Priority 1: Direct-to-Earth assets that meet or exceed LEGS performance
- Priority 2: Lunar relay comm and PNT services
- Priority 3: Lunar surface comm and PNT capabilities

Deep Space Network Lunar Exploration Upgrades (DLEU)

The demand for DSN resources is ever increasing → Upgrades will help ease the demand that Artemis puts on the DSN, and the current DSN will still provide the bulk of the support for Artemis in the near term

Upgrades to DSN's 34-m subnet initiated in FY20

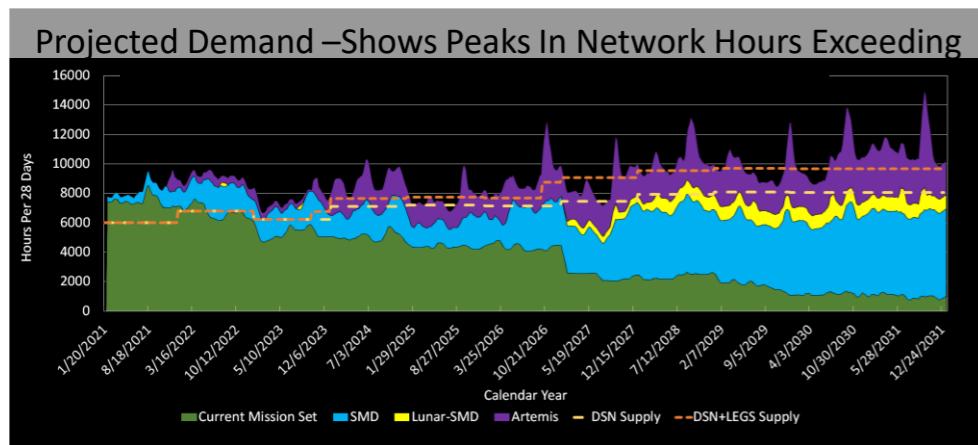
- Modifications are being made to two antennas at each DSN complex - 6 antennas

Antenna upgrades will provide performance enhancements:

- 1) simultaneous services, 2) increased data rates, and 3) low latency data processing

Completion scheduled by Dec 2026

Expanding DSN capacity with DAEP



Lunar Exploration Ground Segment (LEGS)

LEGS requirements: 18-meter class performance with S, X, and Ka services

Three geographically diverse sites for continuous coverage to the Moon

- LEGS 1-3 will be government-owned, contractor operated, with sites 2-3 partners in South Africa and Australia, respectively
- Once ready, sites will be allocated to Gateway support
- O&M support to be negotiated with partners

Additional LEGS capacity being pursued under commercial services procurement, at locations to be determined

LEGS will help reduce contention for DSN resources by absorbing new Artemis demands

SCaN coordinating with SMD to identify opportunities to utilize LEGS for Lagrange missions



Lunar Relay Details

Lunar Communication Relay and Navigation Systems (LCRNS) enhances the capabilities in an incremental fashion

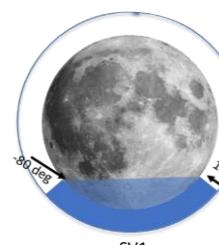
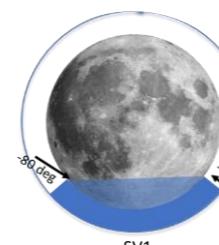
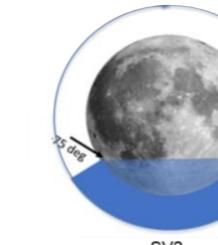
- 3 Phases: Alpha, Bravo, Charlie

After all Initial Operating Capability (IOC) increments are complete Enhanced Operating Capability (EOC) requirements can be added and potentially expand the Lunar Service Volume (SV)

Increases in Service Volume, coverage period, and service type establish minimum requirements for the RFP based on Artemis campaign needs

Services Include:

- Data delivery, real-time and store-and-forward (DTN)
- PNT: 1-way Forward Doppler and Ranging, 2-way Doppler and Ranging, and Time Transfer

Increment	Alpha Services Ready: 2025	Bravo Services Ready: 2027	Charlie Services Ready: 2028	
Service Volume	 SV1	 SV1	 SV2	 SV3
Capabilities	<ul style="list-style-type: none">• Communication support• RF and waveform compatibility with <i>LunaNet Interoperability Specification</i>• Single augmented forward signal (PNT)• Backend connection to the NSN	<ul style="list-style-type: none">• Enhanced communication support• RF and waveform compatibility with <i>LunaNet Interoperability Specification</i>• Multiple augmented forward signal (PNT)• Backend connection to the NSN	<ul style="list-style-type: none">• Full set LCRNS SRD IOC requirements	SV3 identify the <i>minimum</i> space (service) volume where coverage and performance requirements must be met per LCRNS SRD – Covers the entire lunar sphere out to 200km altitude.

The Lunar relay service requirements do not prescribe number of nodes, only service attributes

International Strategy

International partnerships are intended to augment and complement SCaN capabilities

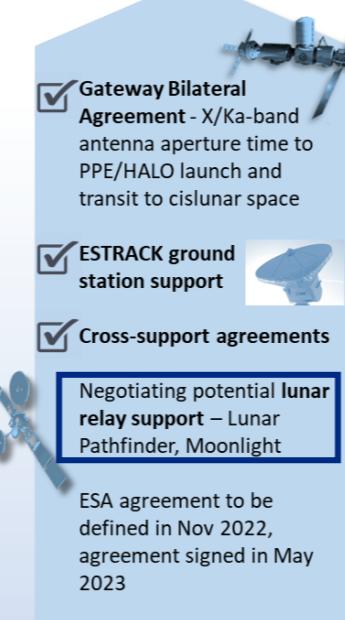
Focus on identifying contributions that are complementary and **interoperable** – partners are paying very close attention to LunaNet

LunaNet is a collaboration focused on interoperability

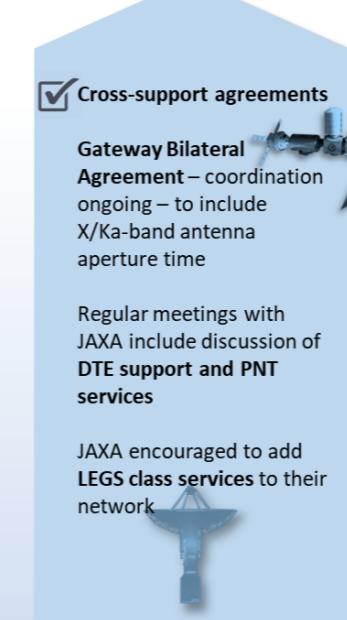
- NASA and ESA are collaborating to create the Draft LunaNet Interoperability Specification – 4th version released in September 2022
- The specification defines standards for lunar communications relay and navigation services and interfaces



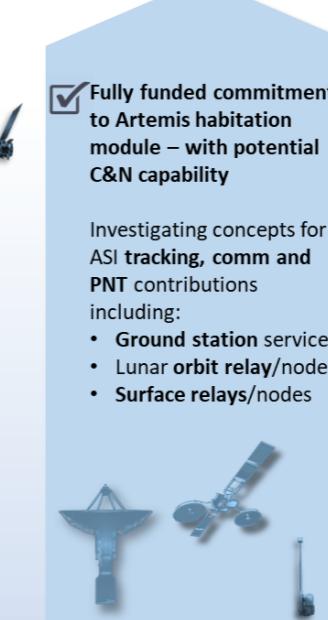
European Space Agency



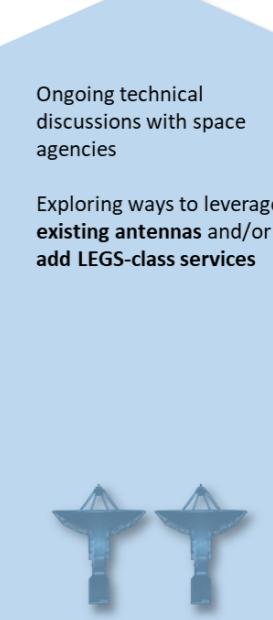
Japan Aerospace
Exploration Agency



Italian Space Agency



Other Space Agencies in South Africa, UAE, Ukraine, Australia, Canada, India, Chile and South Korea



NASA has focused on ESA's Moonlight initiative – collaborating on interoperability, service requirements, and cooperative concept of operations

- Moonlight will be interoperable with NASA relay services by following the LNIS
- NASA relay service requirements shared publicly
- ESA and NASA plan to share capacity, much in the way we exchange DSN and ESTRACK services today

Technical Capability Gaps

Eventually, capacity increases alone will not be sufficient to meet all Artemis mission needs and will drive **capability** enhancements



Surface Wireless Communications

- 3GPP/5G cellular technology for a robust lunar surface C&N infrastructure that is scalable to meet long-term needs
- Essential to address surface and orbital link proliferation
- Enables direct surface/local communication and aggregates data for transition to backhaul
- Potential implementation for Artemis V – connectivity between HLS, LTV, and EVA

Lunar Navigation Services

- “Like GPS, but at/ for the Moon”
- Support near term needs for 10-m surface positioning and 50-m HLS landing knowledge requirements
- Long-term support of complex surface ops, Search and Rescue (SAR) functionality, situational awareness, prediction and avoidance
- Continue studies to define long term needs and architecture

Lunar Optical Communications

- Operational optical communications between Earth and Moon (coherent, multi-gigabit) supports high bandwidth needs, data aggregation and relieves spectrum pressure
- LunaNet compatible, with high-speed DTN
- 1m class operational optical ground station w/adaptive optics
- Pursuing prototype (TRL 6) optical relay payload system

These items are critical initial steps in **capability** development required for eventual Artemis Bas Camp capability

SCaN/Artemis collaborative work is underway to resolve initial capability enhancements needed for Artemis V:

- Surface-to-surface Communications and Navigation needs
- Ongoing definition of PNT needs and solutions



LunaNet - Overview

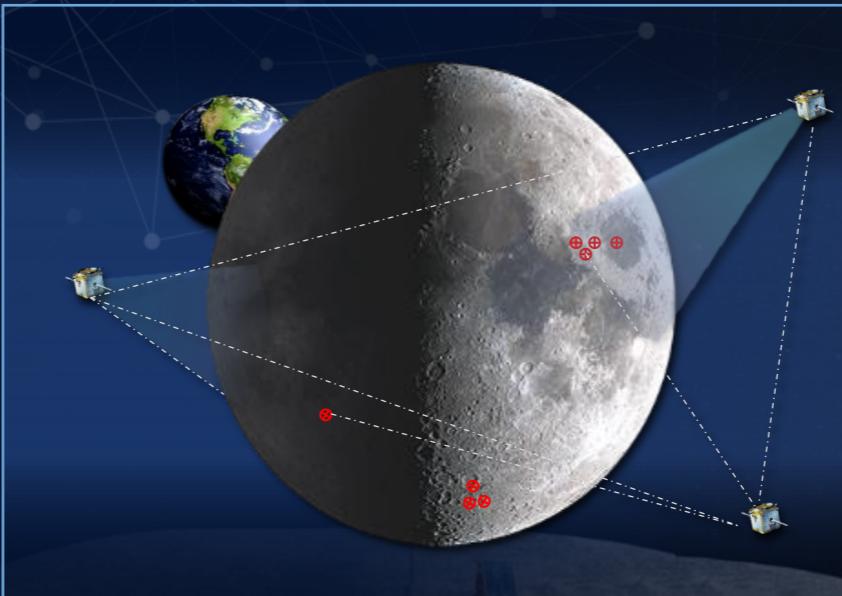
LunaNet is the concept for a set of cooperative communication and navigation networks composed of assets from commercial and government providers serving users at the Moon

LunaNet refers to the framework, not the assets that make it possible and the concept is supported by NASA's international partners

LunaNet concept relies on establishing technical standards for communications and navigation system operations that are widely accepted and used

Delay/Disruption Tolerant Networking (DTN) is a cornerstone of the LunaNet concept/approach

- SCaN is implementing existing DTN protocols while working to expand/standardize other DTN protocols
- DTN standardization will continue via the Consultative Committee for Space Data Systems (CCSDS) for the civil space arena and the Internet Engineering Task Force (IETF) for the commercial sector



Challenges

Initial challenges associated with limited network support capacity:

- Managing fluctuations in Artemis mission timing
- Scheduling around critical events for other network users
- Implementing lunar related network asset upgrades
- Arranging for regular network O&M downtimes

Early Artemis flight element procurements did not prescribe a C&N approach

Capability-focused network enhancements needed in advance of later Artemis missions → Preparations underway

SCaN working to determine the appropriate level of testing needed for the Testing and Verification (T&V) for Lunar missions/assets

- LunaNet Interoperability Specification Document is anticipated to streamline the testing approach for compliant interfaces
- The DoD Hybrid Space Architecture will need to address similar challenges

Spectrum issues associated with shielded zone science needs, and surface wireless allocations will need to be addressed

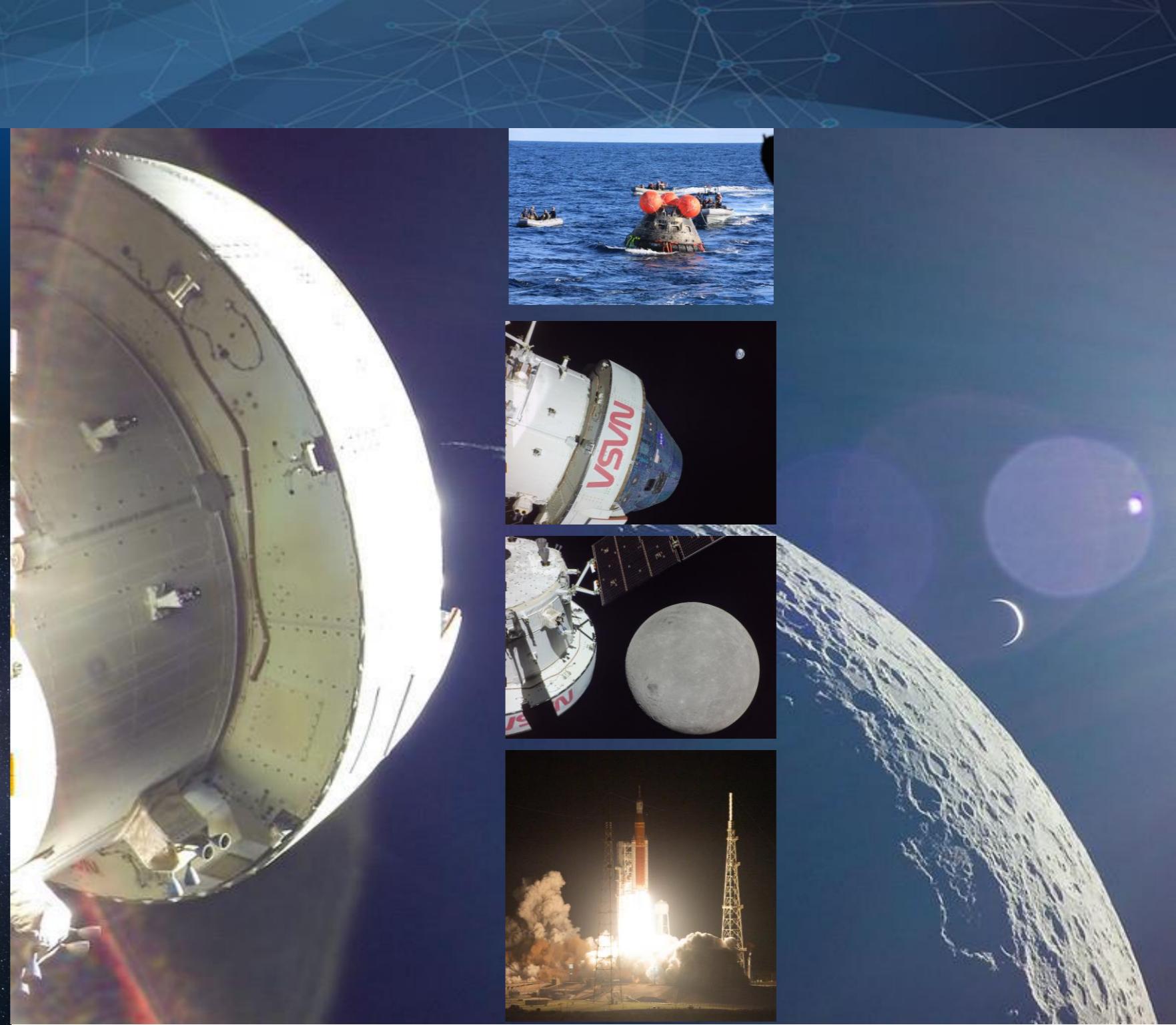
- SCaN engaging with the radio astronomy community and the ITU-R to minimize impacts
- SCaN pursuing regulatory action to get frequency allotments for use on the Lunar Surface
 - > WiFi and 3GPP, particularly 5G solutions are being considered
 - > Space Frequency Coordination Group (SFCG) recommendations include some frequency bands from the 3GPP and WiFi standards



We Are Going

- SCaN has a baseline plan to support through Artemis-V
- As the agency defines lunar and Mars strategy in the 2030s → additional investments will be needed

Collaboration from commercial and government partners is critical for Artemis with LunaNet allowing for network integration



SCaN

Space Communications and Navigation

National Aeronautics and
Space Administration



Exploration, Enabled.

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